日本結晶成長学会
バルク成長分科会

第52回研究会資料集

ーSi単結晶と
Si基板上ヘテロエピタキシャル成長技術ー

共催：ナノ構造・エピタキシャル成長
分科会

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Nitrogen and Carbon Effect on the Formation of Grown-in Defects and Oxygen Precipitation Behavoir

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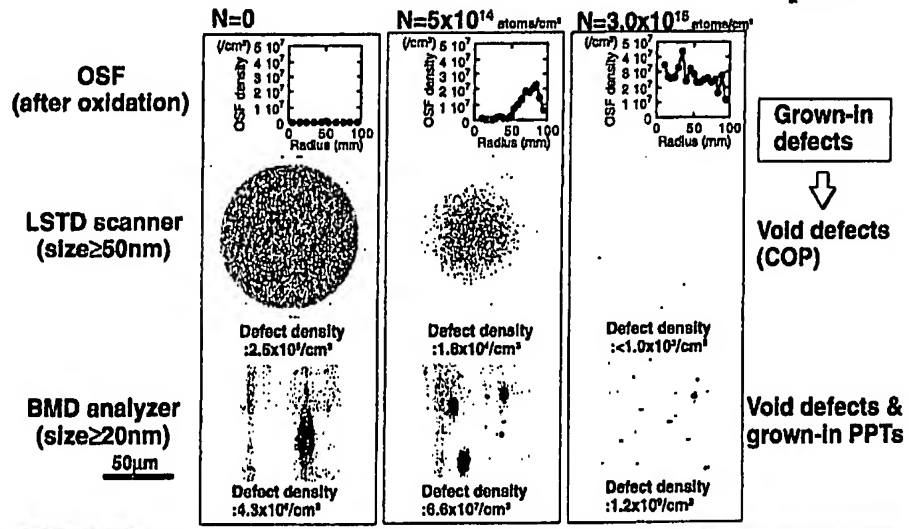
1. Introduction
2. Nitrogen-doping Crystals
   - Grown-in Defects Obserevation
   - Growth Holding Experiments
   - Oxygen Precipitation
3. Carbon-doping Crystals
   - Grown-in Defects Obserevation
   - Growth Holding Experiments
   - Oxygen Precipitation

Experimental

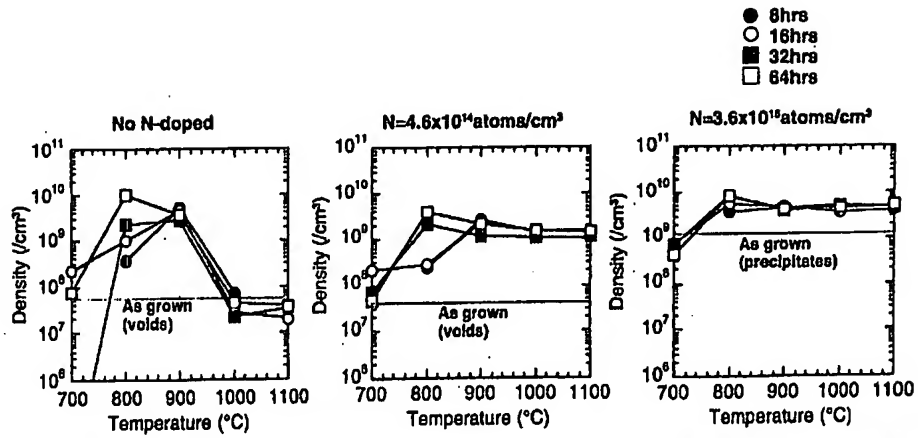
Samples
Diameter : 150mm and 200mm
Resistivity : 8-12 Ωcm
Oxygen : 7-9x10^{17}atoms/cm^3 (JEIDA)
Nitrogen : 2x10^{13}-3x10^{16}atoms/cm^3
(measured by SIMS, calculation)

Evaluation
As grown
LSTD scanner, BMD analyzer : areal distribution, density, size
TEM : Morphology
OSF evaluation
1100°Cx1hr(wet)→Wright Etching
Oxygen precipitation
800°C4hr+1000°C16hr, 700~1100°C 8~128hr
→Reduced Oi (FTIR), precipitate density (BMD analyzer)

Two Types of Grown-in Defects and OSF in N-Doped CZ-Si



Precipitate Density Dependence on Heat-Treatment Temperature

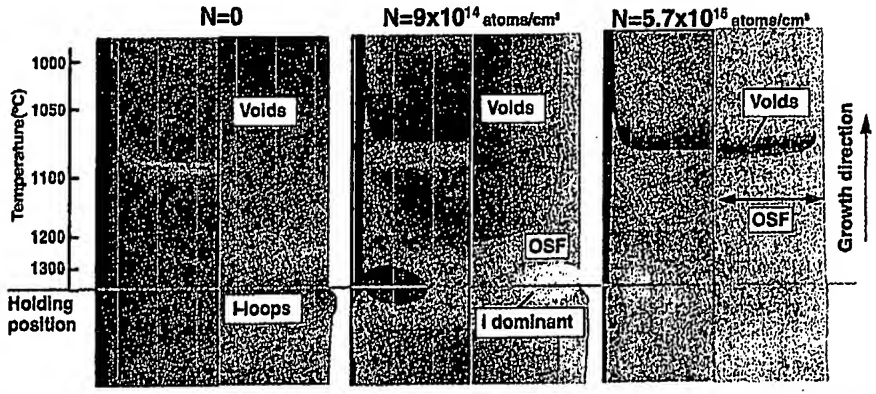


Summary : Grown-in Defects and Oxygen Precipitation in Nitrogen-Doped CZ-Si

- Grown-in defects
  - -Void defects
    - Size :Decrease with nitrogen concentration
    - Density : Increase with nitrogen concentration
    - Morphology :platelike tricrinic
  - -Grown-in oxygen precipitates
    - Density :Increase with nitrogen concentration
    - Morphology : Platelet(with strain field)
    - existence of N and O
  - -Defect regions of nitrogen-doped crystals
    - V region (Voids), OSF region and I region (I-loops)
    - →Determined by Nitrogen concentration and V/G
- Oxygen precipitation
  - -Precipitate density keep constant level regardless of heat-treatment temperature (even in high temp ~1100°C) or time (n=3/2 in Johnson-Mehl Equation)
    - →thermally stable oxygen nuclei exist

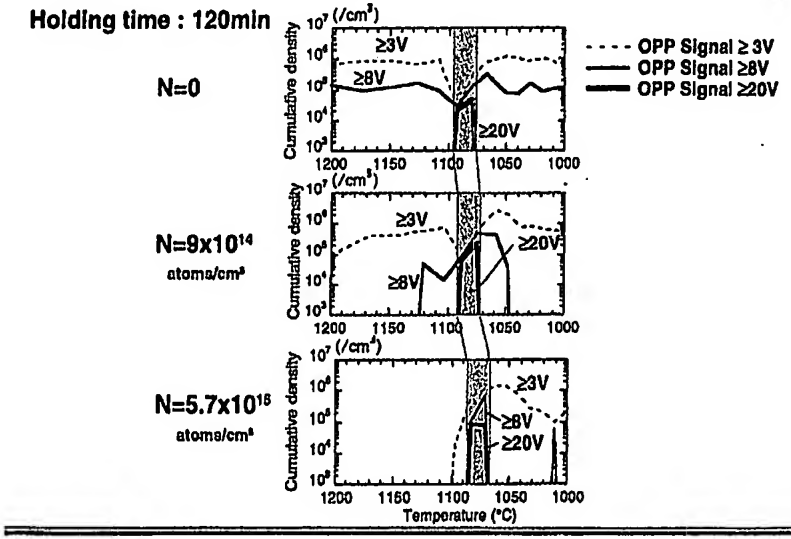
Defect Distribution Change in Growth Held Crystals of Different N Conc.

Holding time : 120min
X ray topograph :800°C4hrs+1000°C16hrs

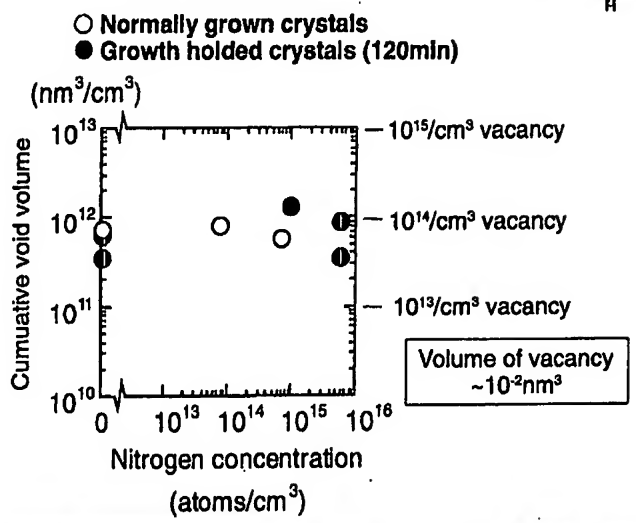


Temperature Dependence of Cumulative Defect Density in growth held crystals of Different N Conc.

Holding time : 120min

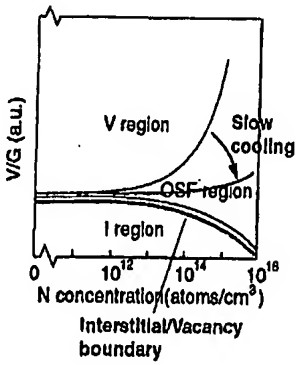


Dependence of Cumulative Void Volume on N Conc.



Summary : Growth Holding Experiments of Nitrogen-Doped CZ-Si

- Results
  - -I region shrinks with increase of nitrogen
  - -Voids formed even in OSF region
  - -Void formation temperature becomes lower
  - -Total void volume is nearly constant regardless of nitrogen concentration
- Mechanisms
  - -Nitrogen suppress the void growth
  - -Residual vacancies form oxygen clusters →thermally stable oxygen nuclei exists



Experimental

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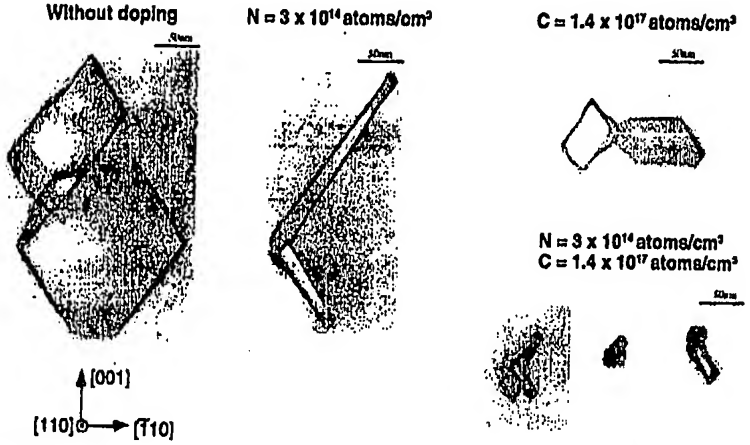
Oxygen : 7-9x10^{17}atoms/cm^3 (JEIDA)
Nitrogen : 3x10^{14}-3x10^{15}atoms/cm^3 (measured by SIMS, calculation)
Carbon : 1x10^{17}atoms/cm^3 (JEIDA)

Evaluation
As grown
- LSTD scanner, BMD analyzer
- Optical Precipitate Profiler (OPP) : Size distribution
- TEM

OSF evaluation
- 1100°Cx1hr(wet)→Wright Etching

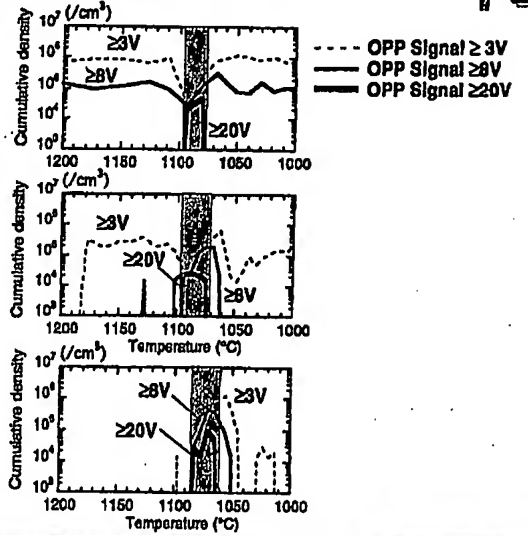
Oxygen precipitation
- 800°C4hr+1000°C16hr, 700~1100°C 8~128hr*
- →Reduced OI (FTIR), precipitate density (BMD analyzer)
- *before and after epi-layer growth (>1100°C)

TEM Images of Voids in N-doped, C-doped and N+C-doped Crystals



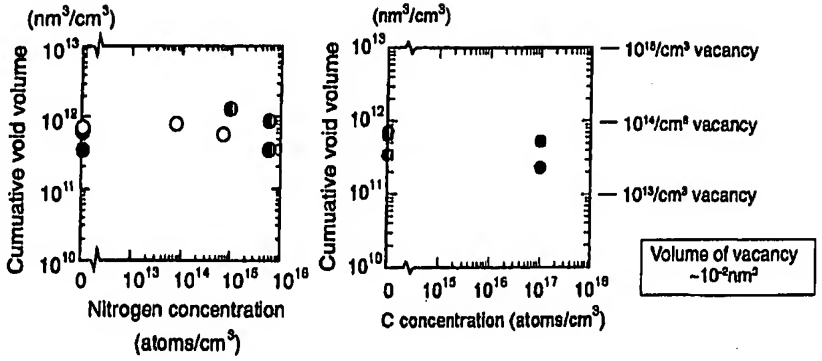
Temperature Dependence of Cumulative Defect Density in growth held crystals (C doped and N+C doped)

Holding time : 120min



Dependence of Cumulative Void Volume on N Concentration or C Concentration

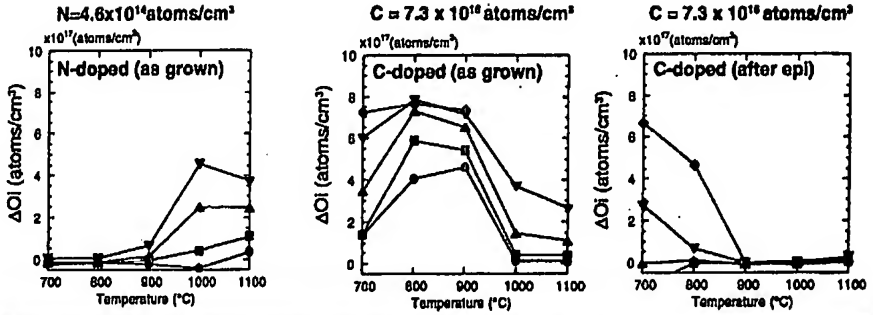
○ Normally grown crystals
● Growth holded crystals (120min)



Reduced Oxygen Concentration Dependence on Heat-Treatment Temperature

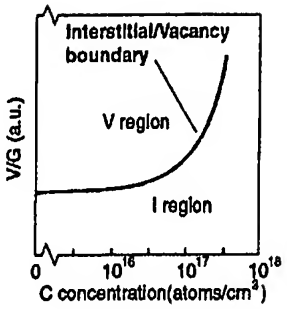
Epitaxial Layer Growth : >1100°C

● 8 hrs
■ 16 hrs
▲ 32 hrs
▼ 64 hrs
◆ 128 hrs



Summary : Growth Holding Experiments of Carbon-Doped CZ-Si

- Results
  - -I region expands with increase of carbon
  - -Void formation temperature becomes lower
  - -Total void volume is nearly constant regardless of nitrogen concentration
- Mechanisms
  - -Induced vacancy concentration becomes lower by Carbon-doping
    - →inconsisitent with the result of total void volume



Summary (Nitrogen and Carbon Effects)

Grown-in Defects Formation
- -Void
  - Same effect (density→increase, size→decrease)
    - →different mechanism
  - N-doping→platelike or rodlike voids
- -Defect Region
  - N-doping shrinks I-region and C-doping expands I-region
- -Grown-in Oxygen Precipitation
  - N-doping induces stable oxygen nuclei (grown-in precipitates)
  - →generate OSF region

Oxygen Precipitation enhancement
- -High temperature (1000~1100°C): N-doping (stable nuclei)
- -Low temperature (≤800°C) : C-doping (nucleation by C)